ISSUE #5: **Forecast Procedures.** If the minimum level for M&I reliability is 75%, what is the mechanism to determine the shortages in between 75% and 100%, i.e. 90%, 85%, 80%?

BACKGROUND:

The M&I contractors are seeking operation and allocation trigger mechanisms for determining shortages between 75% and 100%. This would predict shortages based on storage levels, inflows, and precipitation. They questioned what operating criteria should apply during shortages?

There are two separate processes in the "operation and allocation trigger mechanisms for determining shortages;" the forecast procedures and allocation procedures. They are different procedures.

The Forecast Procedures.

Operations forecasting is done to determine how the current and anticipated water and power resources available to the CVP can be best put to use to meet the objectives of the project. Operations forecasting encompasses many processes including data collection, analysis, review, and communication and may be conducted on a seasonal, monthly, weekly, or daily cycle depending on needs and on the uncertainty of the quantities being forecasted.

Reservoir Refill Potential.

Each river basin has its own distinguishing runoff characteristics. When reservoir operations, defined by storage capacity and downstream demands, are superimposed on the basin characteristics, a relationship between runoff, reservoir releases, and annual reservoir carryover storage emerges. There is an amount of carryover storage (water in storage at the end of September) that through experience and review of project operational history is considered prudent for meeting demand in the following year. The amount varies by facility but it can be loosely defined as the storage level at which it will be possible to regularly meet water demands and constraints without jeopardizing the carryover storage in the upcoming year.

Runoff.

The purpose of developing water supply forecasts is to gain as accurate as possible an assessment of the potential for runoff into each major CVP reservoir and unregulated and unstored flows, including the probable range of the total water year runoff and the distribution of runoff over time. The accurate estimation of runoff is probably the single most important element in planning project operations.

Reclamation, the California Department of Water Resources, and River Forecast Center independently prepare water supply forecasts of seasonal runoff for various streams in the Central Valley. Reclamation forecasts runoff into the following reservoirs

Reservoir	River
Clair Engle	Trinity
Shasta	Sacramento
Folsom	American
New Melones	Stanislaus
Millerton	San Joaquin

Use of Multiple Linear Regression Models.

The system used by Reclamation for forecasting runoff employs sets of multiple linear regression models. Those models were developed by analyses of historical data sets consisting of measured monthly amounts of precipitation, measured snow water content, and calculated monthly amounts of runoff at the reservoir sites.

The general form of the multiple linear regression models used to predict the runoff is an equation in which the estimate of runoff for the remainder of the water year is a function of antecedent runoff, seasonal precipitation to date, and observed snow water content. No estimates of future precipitation or other predictive inputs are used in this process.

The forecasting procedures will develop an array of about 40 multiple linear regression models based on various combinations of the data inputs. The models are in the form of equations which are used to compute estimates of runoff for the remainder of the year. Each of the models will have approximately the same potential for error as measured by statistical parameters. A "Most Probable" forecast is computed by taking the mean of the 40 estimates. This forecast is assumed to have a 50 percent exceedance probability.

Forecast Confidence Limits.

Confidence limits on the seasonal forecast are estimated by an analysis of the error potential of the multiple linear regression models used. This analysis develops probabilistic distribution based on the errors obtained by "hindcasting" the runoff of each historical year, using the same multiple linear regression models as were used to obtain the "Most Probable" forecast. This distribution of "historical" errors is assumed to adequately represent the probable accuracy of the current year's forecast, although in extremely wet or dry years, further special analyses may be warranted to more accurately define the confidence limits.

Customarily the 90 percent and the 50 percent exceedance forecasts are computed, as these define a range within which the eventual runoff should fall 80 percent of the time. The estimation of runoff outside these limits becomes increasingly subject to error based on the limitations of the length of record for the historical data as well as the nature of the multiple linear regression models themselves.

The 90 percent exceedance forecast of runoff for the CVP has been used as a basis for decision-making on water supply availability during the last several years. Because it is a conservative estimate of runoff potential, it translates to a relatively low risk of subsequent reduction in water supply availability, even if precipitation is well below normal. This approach to risk management is important to water users and other resource managers who must make a substantial commitment early in the year on the basis of estimates of the "firm" water supply available.

Depending on conditions, one or more runoff forecasts will be developed for use as input data to Reclamation's operations forecasting model. Reclamation's current forecast procedures develop a total volumetric runoff forecast for the remainder of the water year, for each major water supply reservoir. Typically, confidence limits will be computed for each reservoir's forecast such that a water year runoff will be estimated at the 90 percent and 50 percent levels of exceedance probability. These water year forecasts are then distributed into monthly amounts, generally by use of a pattern wherein each month's forecasted runoff has the same historical probability of exceedance. This pattern may be altered if factors such as antecedent runoff conditions or snow melt potential indicate a different distribution should be used.

Runoff forecasts are initially computed in February, based on precipitation and runoff conditions through January 31, plus February snow course measurements, which will normally be taken within a few days of the end of January, and adjusted, if necessary, to represent end of the month conditions of the snow water content. Forecasts are computed again in March, April, and May, and updated data inputs.

Forecasts may be performed earlier than February, but the potential inaccuracy of such early forecasts raise the possibility of very large forecasting errors. For many water management purposes it is less risky to use assessments of runoff potential that are derived simply from the statistical properties and the rankings of historical runoff data. As shown in Figure 1, by February 1, a little over 50 percent of the rainy season is past, and knowledge of runoff potential is sufficient to outweigh the risks of inaccurate forecasts.

The final forecasts are computed in May of each water year, although adjustments to these forecasts will be made in subsequent months based on observed runoff, the timing of the peak of snowmelt runoff, and the shape of the recession of runoff. Furthermore, in the American, Stanislaus, and San Joaquin Basins, the forecast of natural runoff must be converted to "operational reservoir inflow" by adjusting for the effects of regulations by upstream reservoirs, imports and exports from the basin, and consumptive use if appropriate.

Accuracy of Runoff Forecasts.

The accuracy of the runoff forecasts in any given year is highly dependent on the pattern of the precipitation in that year, a factor that cannot be well predicted. However, the patterns of precipitation and runoff in the Central Valley have exhibited two important tendencies; the rainy season generally occurs between November and April and snowmelt runoff typically occurs between April and July. Because of these generalized tendencies, the accuracy, or, conversely, the error potential of the water year runoff forecasts, can be depicted as a "funnel diagram." The general tendency for forecast errors over time is that they tend to get smaller as the year proceeds and more information becomes "observed" and less remains to be "estimated."

Reclamation, the Department of Water Resources and National Weather Service in Sacramento all prepare independent forecasts of runoff for each CVP water supply reservoir. Prior to final adoption of the runoff forecast for use in operations planning, Reclamation consults with and compares forecasts with personnel in the Department of Water Resources and National Weather Service. Based on those consultations, Reclamation may decide to adjust its forecast. An important element of the forecast consultations is the discussion of any unique conditions of the current water year and how those may affect the accuracy of the runoff forecasts.

Most of the precipitation data used by Reclamation is collected or reported by either the Department of Water Resources or the National Weather Service. All of the snow water content data is collected and reported by the Department of Water Resources's California Cooperative Snow Surveys. Reclamation has entered annual agreements with each of these agencies which help support data collection, processing and reporting, and also help support runoff forecasting efforts.

Accretions/Depletions.

The term Sacramento River accretions/depletions refers to the difference between the amounts of water released to the Sacramento and its tributaries by the CVP and SWP, and the amount which flows past Sacramento and into the Delta. Depending on the time of year and hydrologic conditions, this amount may represent a net gain (accretion) or a net loss (depletion). Accretions/Depletions are forecasted for both short-term and long-term operations planning purposes. Short-term forecasts, up to about seven days in the future are used to estimate inflows to the Delta, at key points on the Sacramento River, and to provide guidance to project operators on predicting release requirement 5-7 days in advance (the maximum travel time from Keswick Dam to the Delta). Such short-term predictions of accretions/depletions may make use of real time flow data, temperature and weather forecasts, travel time, non-project reservoir releases, existing trends in accretions and depletions, and on advice and input from some of the major districts using water on the Sacramento.

Longer range forecasts of accretions and depletions are made for purposes of planning operations on a seasonal or monthly basis. For this purpose, accretion/depletions are treated as monthly quantities and are customarily forecasted or estimated for 12 months into the future. This discussion will focus on the long range forecasts of accretions/depletions.

Annually, the net accretions/depletions has ranged from about 1.0 million acre-feet (in 1977) to over 20 million acre-feet (1983). The range of this quantity, in addition to the scope and complexity of the processes within the Sacramento Valley add to the problems of forecasting accretions/depletions accurately. Fortunately, certain predictable tendencies help to characterize the accretions/depletions. Furthermore, operational considerations limit the range of accretions which have any practical effect on project operations to periods of Delta "balanced" conditions. When "excess" conditions exist, the projects are storing and exporting as much water as possible.

Thus the accuracy of the estimate of accretions/depletions is significant to project operations only within the range that is associated with the projects capability to respond operationally.

Forecasts of Delta requirements are perhaps the most difficult to make. There are so many factors that can influence conditions in the Delta, that it is unlikely that any forecast will succeed in correctly identifying them all. For example, there are four major water export locations in the Delta, but literally hundreds of minor exporters. There are forecasted tide tables, but no long-term forecasts of barometric pressure which can affect the magnitude of the tide; and there are no long-term forecasts of daily meteorological events. Despite the inaccuracies, forecasts of Delta requirements are necessary. Without them, planning for upstream reservoir operations and south of the Delta water deliveries would be impossible and the reliability of the projects would be compromised.

The CVP operating criteria has undergone tremendous changes with the Bay Delta Accord, the Water Quality Plan, the B-2 Accounting as a result of the Central Valley Project Improvement Act of 1992 (CVPIA), the Endangered Species Act (ESA), etc. The CVP operating criteria must be flexible. It is controlled by regulatory requirements (State Water Resources Control Board), statutory requirements (CVPIA, ESA, etc.), hydrological requirements (the 6-year drought (1989-1995), and operational decisions to maximize the use of CVP water supplies to its Project purposes.

Five indices that are used in the determination of available water supplies include: Shasta Index, 40/30/30 Index, Sacramento River (4 Rivers) Index, and San Joaquin River Index (60-20-20 Index). These indices are described in the table on the following page. The 25% maximum shortage language is associated with the "Classic Yield" definition where shortages of up to 25% of the time occurred during the 1928 to 1934 period. Both the Shasta Index Critical Year and the 40/30/30 Critical Year have four critical years in the 1928 to 1934 period. The primary difference is the frequency that shortages occur over the long term (70 year) planning period. Under the Shasta Criteria shortages could be expected about 10% of the time and under the 40/30/30 Index shortages could be expected approximately 17% of the time. It is Reclamation's position that the Shasta Index is outdated in light of the other indices that more accurately reflect the hydrologic situation on the Sacramento River and Central Valley Basin as a whole.

ISSUES:

What operating criteria should apply during shortages? We currently operate under the CVP Operations Criteria and Plan (CVP-OCAP) developed in 1992 as modified by policies and agreements to meet the ever changing environment. The 1992 CVP-OCAP identified the many factors influencing the physical and institutional conditions and decision-making process under which the project operated at that time. Regulatory and legal requirements were explained, alternatives operating models and strategies described, and the Water Year Operations Plan were provided. Elements of the CVP-OCAP have changed since 1992 as a result of regulatory requirements mentioned above, i.e., the Water Quality Plan, the B-2 Accounting, the ESA, etc.

Is there more than one equitable approach that may be utilized in different geographic locations? Water supply is allocated based on CVP water supplies that are available. There may be further shortages to that allocation depending on the different geographic locations.

Should minimum level, trigger mechanisms, or operating criteria vary between geographic or hydrologic regions? The 1992 CVP Operating Criteria established minimum levels and trigger mechanisms and they vary between geographic or hydrologic regions. The American River for example has primarily M&I use and may have limited water supplies available from the Upper American River. Thus with primarily M&I use, those on the American River may suffer shortages more often than the Sacramento River M&I contractors below the confluence of the American and Sacramento Rivers.

What special provisions are needed for M&I uses in areas or watersheds of origin or in the Delta? None. Reclamation recognizes and complies with California's area of origin statutes in it's operation of the CVP. These statutes do not, however, grant any CVP contractor or CVP purpose of use any special priority or preference to water over any other CVP contractor or CVP purpose of use. Therefore, the area of origin statutes of California law do not establish any priority for the allocation of CVP contractual water supplies.

Shouldn't M&I Contractors shortages be tied to the Shasta Criterion same as the Sacramento River Water Rights settlement contractors? No. The Shasta Criterion was developed in the 1940's and is criteria utilized in the early Sacramento River settlement contracts and the San Joaquin Exchange contracts. This criteria was based on the Shasta Reservoir inflow and is reflective of the hydrologic data available at that time. The M&I Contractors are not water rights settlement contractors based on the impacts of Shasta Dam. The M&I Contractors benefit from all of the CVP reservoirs. The M&I and agricultural contractors shortage provisions should be based on the same criteria and that should be the most up-to-date criteria available not criteria from the 1940's already proven that there is better criteria available.

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INDICES USED IN CURRENT SHORTAGE ALLOCATION

Index	Occurrences 28 to 34 Period	Occurrences 22 to 90 Period	Description	Comments
Shasta Criteria Critical Year	4	7 (10%)	A Critical year exists when the forecasted full natural inflow to Shasta Lake for the current water year is equal to or less than 3,200,000 AF **Or** the total accumulated actual deficiencies below 4,000,000 AF in the immediately prior water year or series of successive prior water years each of which had inflows of less than 4,000,000 AF together with the forecasted deficiency of the current water year , exceed 800,000 AF.	Used as basis for deficiencies to Sacramento River Settlement contractors and DMC Exchange contractors.
40/30/30 Sacramento Valley Critical Year	4	12 (17%)	40/30/30 Index is defined as 0.4 times current year's April-July Sacramento Valley unimpaired runoff plus 0.3 times the current October-March Sacramento Valley unimpaired runoff plus 0.3 times the previous year's index (capped at 10,000,000 AF). There are five year types Wet, Above Normal, Below Normal, Dry, and Critical.	Used for Bay/Delta Accord.
Sacramento River (4 Rivers) Index	4	13 (19%)	The Sacramento River Index is determined as the sum of the forecasted Sacramento Valley unimpaired runoff for the current water year for the Sacramento River above Bend Bridge, the Feather River total inflow to Oroville Reservoir, the Yuba River at Smartville, and the American River total inflow to Folsom Reservoir.	Basis for D-1485 Standards. Used in Winter Run Biological Opinion and Temperature Control.
60-20-20 San Joaquin Valley Critical Year	4	13(19%)	60/20/20 Index is defined as 0.6 times current year's April-July San Joaquin Valley unimpaired runoff plus 0.2 times the current October-March San Joaquin Valley unimpaired runoff plus 0.2 times the previous year's index (capped at 4,500,000 AF). There are five year types Wet, Above Normal, Below Normal, Dry, and Critical.	Used for Bay/Delta Accord.